

A faint world map is visible in the background of the slide, rendered in a light blue color against the darker blue background. The map shows the outlines of continents and some internal grid lines.

HEMCO: **H**armonized **E**missions **C**omponent  
as a versatile multi-model emissions component  
implemented in MUSICA/CAM-chem

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CESM Working Group Meeting – AMWG/CCWG/WAWG Joint Session: New Development Plans

<https://doi.org/10.5194/gmd-14-5487-2021>

Emissions are at the heart of atmospheric chemistry modeling  
yet have several limitations in current models

## **Need to preprocess inventories**

to model grid

to target chemical scheme

with ad-hoc tools

using time and disk space



## **Difficult to share data and code**

## **Source of human error**

in pre-processing

for different cases/variations

in reproducing past results

## **Wide range of sources**

possible inconsistent treatment

double counting/undercounting

HEMCO is a powerful on-line emissions component that can (mostly) be controlled by a text-based *configuration file*

```
# ----- REGIONAL INVENTORIES -----
--> APEI : false
--> NEI2011_HOURLY : false
--> NEI2011_MONMEAN : false
--> MIX : false
--> DICE_Africa : false
# ----- GLOBAL INVENTORIES -----
--> CEDS : true
```

### HEMCO Emissions Data Library

*Gridded global and regional inventories*

### HEMCO Extensions

*State dependent emission algorithms*

*(Biogenic, Dust, Lightning, ...)*

*& GFED, Volcano, Ship Plumes...*

**CAM-Chem/MUSICA**

**CESM-GC**

GEOS-Chem 'Classic'

GCHP

WRF-GC

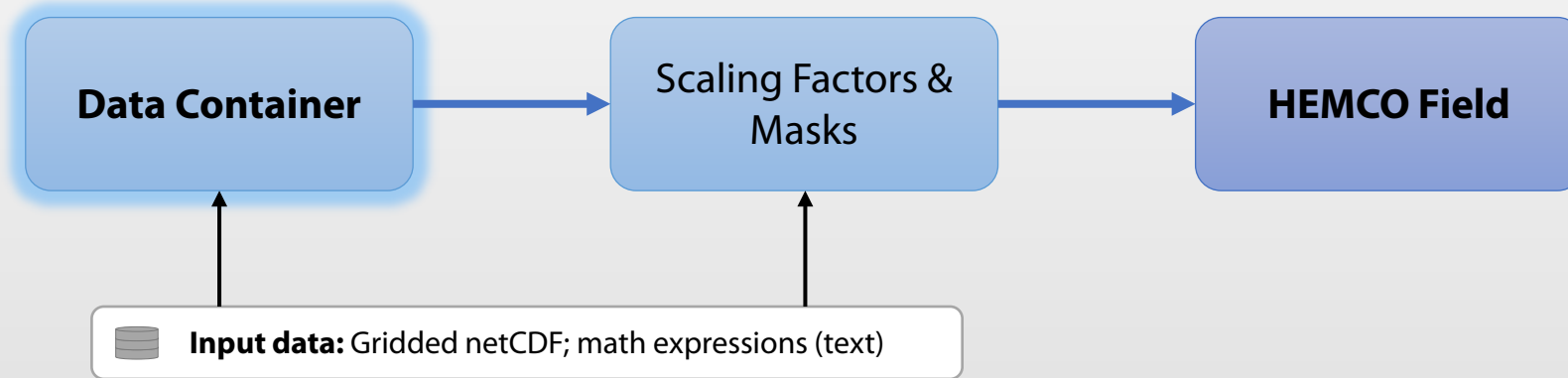
NASA GEOS (GEOS-GC)

**Scaling, masking, and adding emissions from different sources, regions, and species at runtime on a user-specified grid without preprocessing!**

*Keller et al., 2014; Lin et al., 2021*

# How does HEMCO accomplish this?

“**HEMCO Fields**” are the basic building block



$\emptyset$	Container name	Source netCDF file	Variable	Date range (Y/M/D/H)	Cycling Opt
0	CEDS_NO_AGR	NO-em-total-anthro_CEDS_\$YYYY.nc	NO_agr	1970-2017/1-12/1/0	C
xy	kg/m <sup>2</sup> /s NO	25/1234	1	5	
	Dim Unit	Model Species Name	Scaling Factors	Category	Hierarchy

**Example:** Emissions data container in HEMCO.

Tokens like \$YYYY, \$MM, \$DD, \$HH are automatically replaced into file names

- Cycling option:** e.g.,
- C: cycle closest
  - R: only use within range
  - RA: range, otherwise avg
  - A: average
  - **I: interpolate nearest two**
  - E: must be exact match

# Putting it together: HEMCO configuration file demo

**(1) Collection switch**

```

### BEGIN SECTION EXTENSION SWITCHES
0   Base           : on   *
   --> CEDS        :      true
   --> MEIC         :      true
### END SECTION EXTENSION SWITCHES ###
    
```

**(2) Data containers**

Data container name

Data source (File name, variable, temporal range and refresh frequency, cycling option, spatial dimensions)

Units and model species ("\*" if not emissions data)

Category and hierarchy

```

### BEGIN SECTION BASE EMISSIONS
(((CEDS
0   CEDS_EOH_AGR   CEDS_EOH_YYYY.nc   VOC1   1970-2017/1-12/1/0   C xy   kg/m2/s   CH3OH   91   1 1
0   CEDS_EOH_AGR   CEDS_EOH_YYYY.nc   VOC1   1970-2017/1-12/1/0   C xy   kg/m2/s   C2H5OH  92   1 1
0   CEDS_NO_AGR    CEDS_NO_YYYY.nc    NO_agr  1970-2017/1-12/1/0   C xy   kg/m2/s   NO      25   1 1
0   CEDS_NO_IND    CEDS_NO_YYYY.nc    NO_ind  1970-2017/1-12/1/0   C xyL*  kg/m2/s   NO      25/316 1 1
)))CEDS
(((MEIC
0   MEIC_NO_AGR    MEIC_NO.05x0666.nc NO_agri 2000-2017/1-12/1/0   C xy   kg/m2/s   NO      301/1009 1 2
)))MEIC

* UV_ALBEDO      uvalbedo.geos.2x25.nc UVALBD 1985/1-12/1/0   C xy   percent *   -   1 1
### END SECTION BASE EMISSIONS ###
    
```

**(3) Scaling factors and masks**

```

### BEGIN SECTION SCALE FACTORS
25   EDGAR_TODNOX   EDGAR_hourly_NOxScal.nc           NOxscale  2000/1/1/*   C xy   unitless 1
301  MEIC_DOW_AGR   0.994/1.001/1.001/1.001/1.001/1.001/1.001  -   -   - xy 1 1
316  INDUSTRY_LEVS  vert_alloc.nc                       g_industry 2017/1/1/0   C xyz 1 1

91   VOC1toCH3OH    0.15   -   -   - xy 1 1
92   VOC1toC2H5OH  0.85   -   -   - xy 1 1
### END SECTION SCALE FACTORS ###

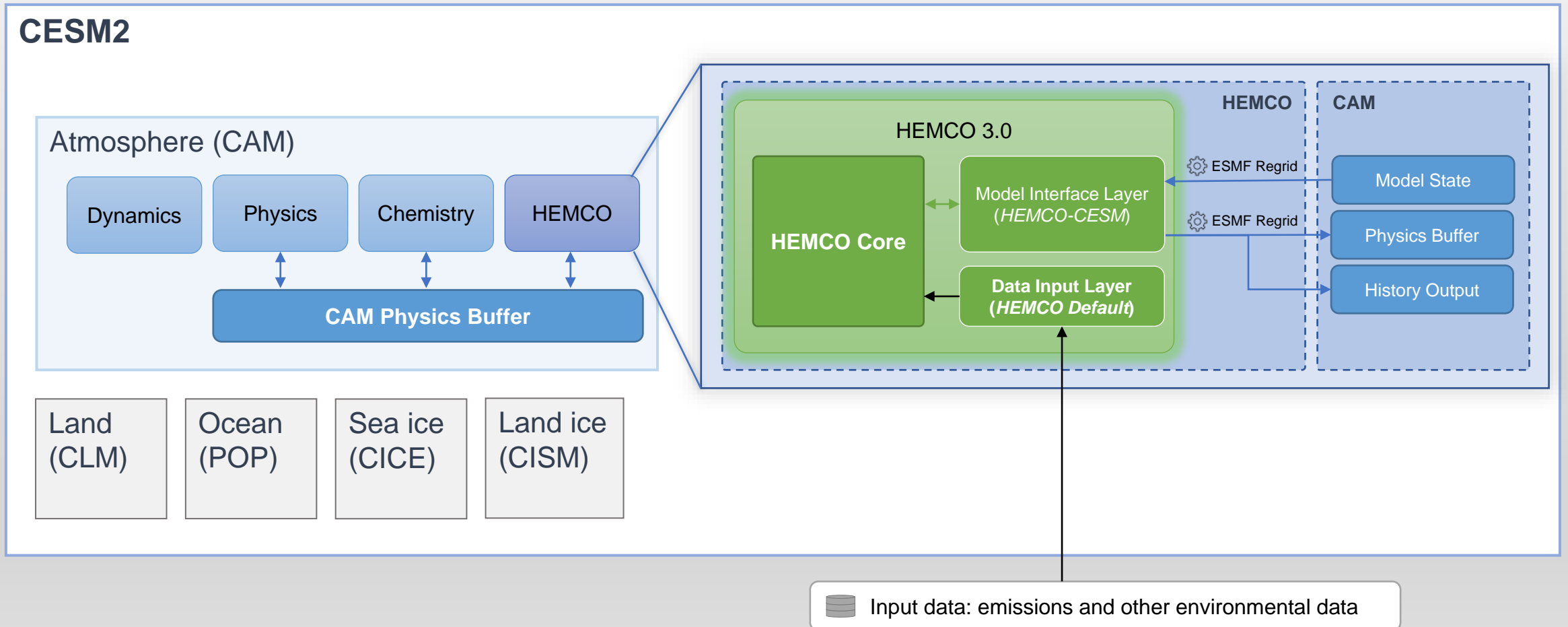
### BEGIN SECTION MASKS
1009 CHINA_MASK     China_mask.generic.1x1.nc MASK     2000/1/1/0   C xy 1 1 70/10/130/60
### END SECTION MASKS ###
    
```

CEDS Collection

MEIC Collection

# HEMCO 3.0 as implemented within CESM2 – HEMCO\_CESM interface

**HEMCO as a separate component in the atmosphere allows serving of data to any atmospheric component, independent of “the outside world”**

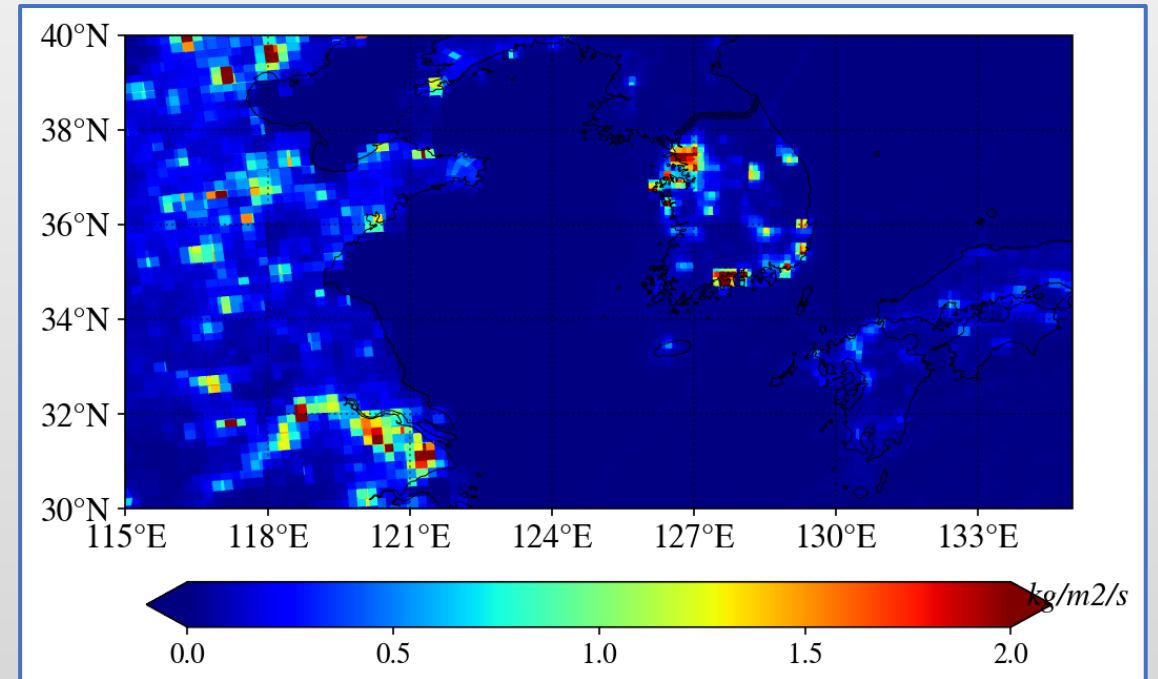


# HEMCO is fully operational in CESM2 – MUSICA/CAM-chem

- **All HEMCO emissions are computed at runtime and available in the physics buffer.**
- Also available as output fields in the master field list.
- Grouped by species: HCO\_NO, HCO\_NO2, etc.
- Available over the entire vertical if emissions are 3-D (extfrc\_1st) or over the surface only otherwise.

## HEMCO-CESM output (HCO\_NO)

On MUSICA Korea grid, HEMCO internal res 0.15x0.15deg



*Using Vivaldi-a package for Plot\_2D  
Credit to Duseong Jo for Korea MUSICA Grid*

I want to give HEMCO/HEMCO-CESM a try!

- Thank you! 😊
- **HEMCO on the CAM-chem wiki:** <https://wiki.ucar.edu/display/camchem/HEMCO>
- **Git repositories:**
  - **HEMCO** Core code, including Extensions: <https://github.com/geoschem/HEMCO/>
  - **HEMCO-CESM** interface: [https://github.com/ESCOMP/HEMCO\\_CESM](https://github.com/ESCOMP/HEMCO_CESM)
  - **Configuration files** for CAM-chem/GEOS-Chem within CESM: [https://github.com/jimmielin/HEMCO\\_CESM\\_configs/](https://github.com/jimmielin/HEMCO_CESM_configs/)
- Please feel free to reach out to me with any questions or bugs!
- Generic HEMCO questions can be asked at the HEMCO GitHub as well (supported by the GEOS-Chem Support Team)



# Other useful resources

- HEMCO User's Guide: <https://hemco.readthedocs.io>
- HEMCO references:
  - HEMCO 3.0 – implementation in several models, including CESM: <https://gmd.copernicus.org/articles/14/5487/2021/> (Lin et al., 2021)
  - HEMCO 1.0 – original reference: <https://gmd.copernicus.org/articles/7/1409/2014/> (Keller et al., 2014)
- HEMCO in MUSICA:
  - Pull request with setup instructions: <https://github.com/ESCOMP/CAM/pull/560>
- My email: [hplin@seas.harvard.edu](mailto:hplin@seas.harvard.edu)